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SHOCK WAVE PRESSURES OVER CORAL SAND AND MUD FROM THE NOTS 301D LINE CHARGE

by

M. A. Thiel

ABSTRACT: Underwater pressure measurements obtained on four bottom shots of the NOTS 301D demolition line charge (700 ft long, 4200-lb of Comp. C-4) are presented. The pressure field on the bottom around the line charges appeared to be nearly rectangular in shape; i.e., high pressures off the side of the charge and very low pressures off the ends. The pressures were highest for charges fired over a coral sand bottom in 55 ft of water; pressures from charges fired over a coral sand bottom in 12 ft of water were approximately equal to those over a mud bottom in 60 ft of water. The pressures from the latter two conditions were about 40 to 60 per cent lower than those obtained for the first condition. There was considerable scatter among the results; this was probably due mainly to variations in the properties of the bottom along the length of each charge.

UNDERWATER EXPLOSIONS DIVISION
EXPLOSIONS RESEARCH DEPARTMENT
U. S. NAVAL ORDNANCE LABORATORY
WHITE OAK, SILVER SPRING, MARYLAND

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SHOCK WAVE PRESSURES OVER CORAL SAND AND MUD FROM THE NOTS 301D LINE CHARGE

This report gives the results of pressure measurements over two types of bottom around the NOTS 301D Demolition Line Charge. This line charge has been proposed as a means of mine field clearance. The results obtained in this work are only applicable to the conditions of these tests and cannot be safely extrapolated to other conditions.

The work discussed in this report was performed under WEPTASK No. RUME-4E-000/212-1/F008-10-04 PA 002, Supporting Research in Underwater Explosives and Explosions, which is a continuing research task to provide basic data on explosives and underwater applications of explosives.

R. E. ODENING
Captain, USN
Commander

C J Aronson

C. J. ARONSON
By direction

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1. INTRODUCTION

Although line charges have been under consideration as a brute force method of mine clearance for some time, little is known about the pressure field around a line charge at ranges of importance for mine clearance. A few pressure measurements have been made on the perpendicular bisector and off the ends of relatively short line charges [a, b]*. Several countermining tests of line charges have been done; however, pressure measurements were not made [c, d].

Recently the Key West Test and Evaluation Detachment (KWESTEVDET) performed a series of countermining tests of the NOTS 301D Demolition Line Charge. The Naval Ordnance Laboratory made pressure measurements on these tests. This report presents the results of these pressure measurements.

2. EXPERIMENTAL PROCEDURE

2.1 General Plan: The tests were conducted during the spring and summer of 1962. Three of the four tests were done at Key West, Florida, and the fourth was done at the NOL Test Facility, Solomons, Maryland.

The primary purpose of the tests was the determination of mine damage as a function of distance. A mine field was set out for each shot with the position of each mine carefully determined. After the shot mine damage was evaluated by examining the recovered mines.

2.2 Charge: The charge used on all shots was a 700-ft length of NOTS 301D Demolition Line Charge. The line charge was approximately 4 inches in diameter and contained 6 pounds of Composition C-4 per foot. A more complete description of the 301D line charge may be found in reference [d].

2.3 Water Depth and Bottom: Table 1 summarizes water depths and bottom types for the four shots. On all shots the line charge was on the bottom.

TABLE 1

SHOT CONDITIONS

Shot Number	Nominal Water Depth (ft)	Bottom	Site
1	55	Coral Sand	Key West
2	55	Coral Sand	Key West
3	12	Coral Sand	Key West
4	60	Mud	Solomons

*All such letters refer to the List of References on Page 9 .

Shots 1, 2, and 3 were fired over the same type of bottom. It consisted of coral sand, shell and coral fragments covered with an overlying silt layer several inches thick. Shots 1, 2, and 3 were fired in areas several miles apart.

The shot 2 bottom appeared to be somewhat harder than that of shot 1. Shot 1 formed a crater about 3 ft deep and 6 ft wide in the bottom while the crater of shot 2 was about 1 ft deep and 2 ft wide; this indicates that there were probably significant differences in the bottom material for the two areas. The bottoms appeared identical to the divers with the exception of the depth of the overlying silt layer. The shot 1 bottom was covered with 4-5 inches of silt while the shot 2 bottom was covered with 2-3 inches of silt.

The shot 4 bottom was mud which was several feet deep.

2.4 Instrumentation. Instrumentation for the tests consisted of piezoelectric gages and associated recording equipment for obtaining pressure-time records, and ball crusher gages for peak pressure measurements. Four piezoelectric gages and 150-200 ball crusher gages were used on each shot.

The piezoelectric gages were 7/8-inch, single-ended, tourmaline gages. The gages were connected by 2,000 foot long, low-noise co-axial cables to the recording equipment. The recording equipment was an Electron Tube Corporation four channel oscilloscope modified by NOL. The camera used for recording the oscilloscope trace was a General Radio high speed streak camera. Associated with the recording equipment were timing and firing circuits built by NOL. The detonation pulse was furnished by NOL, allowing a zero time mark to be put on the pressure-time records.

The ball crusher gage is a mechanical gage in which a piston deforms a copper sphere as the piston is acted on by the shock wave. The peak pressure seen by the gage may be calculated from the sphere deformation if the shape of the shock wave is known. If the shape of the shock wave is not known, an equivalent step pressure can be calculated. The equivalent step pressure is the average pressure over the first 180-200 microseconds of the shock wave. A more complete description of the gage may be found in reference [e]. The ball crusher gages used in this series of tests were waterproofed with rubber diaphragms as described in reference [e].

2.5 Gage Rigging: On shots 1 and 2 each piezoelectric gage was attached to a mine if the mine was located at a chosen gage position. At other locations the gages were attached to empty mine crates. On shot 3 and shot 4 all the piezoelectric gages were attached to mine crates to avoid shielding of the gages by the mines. The gages were mounted about one foot from a mine or mine crate; the gage cable was attached to the unit with a C-clamp. The gages were approximately 3 to 6 feet off the bottom.

The piezoelectric gage cables were laid on the bottom between the shot location and the instrument platform. The instrument platform for the first three shots was the USS SALINAN (ATF 161). The instrument platform for the fourth shot was a barge. The recording equipment was housed in a transportainer on the fantail of the ship or on the deck of the barge. The USS SALINAN was anchored 1200-1500 feet from each line charge at detonation time; the barge was anchored 400-500 feet from the line charge.

Two ball crusher gages were mounted on each bottom mine. The gages were secured on a bracket welded to the mine. At shot time the bracket was on top of the mine and the gages on the bracket pointed up. On mine crates the gages were mounted a few inches apart on the frame of the mine crate. The ball crusher gages pointed up when the mine crate was in position on the bottom.

On shot 2, a few MK 16 moored mines were used. Ball crusher gages were mounted on gage blocks which were attached to the mooring cable a few feet below the mine. These ball crusher gages were approximately at mid-depth.

On shot 4 a few ball crusher gage blocks were suspended below surface buoys. The buoys were directly above the line charge and the gage blocks were about five feet below the water surface. Only one of these gage blocks was recovered.

2.6 Test Array: Tables 3, 4, 5, and 6 list the locations of the mines or mine crates on which ball crusher gages were mounted. Table 2 lists the locations of the piezoelectric gages. The locations are given in terms of a rectangular coordinate system. Figure 1 shows the coordinate system. The detonation end of the line charge is the origin. Location is specified by a pair of numbers; the first number is the X coordinate; the second number if the Y coordinate.

The array for each shot was set in the following manner: Divers laid out the pattern of the array by staking out ropes on the bottom. Positions of the charge, the mines and mine crates had been carefully measured and marked on these ropes. Mines and mine crates with ball crusher gages attached were lowered from the ship and guided into position by the divers. The next step was the lowering and placing of the line charge by divers. The last step for the divers was to lay the piezoelectric cables and to place the piezoelectric gages in their proper positions. Accuracy of placement of mines and mine crates was estimated by KWESTEVDET personnel to be within three feet of marked positions.

The mines and mine crates of Shot 4 partially or completely buried themselves in the mud. The line charge sank partially into the bottom at some places along its length. All piezoelectric and an unknown number of ball crusher gages were buried in the mud.

3. PIEZOELECTRIC GAGE RESULTS

3.1 Description of Records: Figures 2, 3, and 4 show tracings of the piezoelectric gage records obtained on shots 1, 2, and 4. On shot 3, the recording camera did not start; peak pressures were obtained from two records.

Shots 1 and 2. The pressure-time records obtained on shots 1 and 2 are very similar to those obtained from spherical charges fired on sand bottoms [f]. All records show long, low amplitude precursors followed by shock waves and surface cutoff. The shapes of the pressure-time records show some variation between the two shots. The initial decay of the shock wave was exponential in some cases and linear in others. More of the records taken on the second shot show linear decay than do the records of the first shot. One of the shock waves (PE-4, shot 2) had a slow rise time.

Shot 4. The three pressure-time records obtained on shot 4 are similar to those obtained from spherical charges fired on a mud bottom [f]. The decay of the shock wave was exponential on two of the three records. On another record (PE-3) the shock wave had a slow rise time.

3.2 Record Analysis: Table 2 shows the data obtained from the piezoelectric records. Arrival times, time constants and peak pressures are shown; arrival times were measured from the detonation pulse. On shot 4 the timing signals had to be interpolated for a short time interval. Hence, the time values for shot 4 are not as accurate as those for shots 1 and 2.

The shock wave pressure includes the precursor, i.e., the shock wave peak pressure was measured from the base line to the peak. The precursor pressure was measured at the shock front.

The time constant was measured only on shock waves that had an exponential decay. It is the time for the pressure to decay to 1/e of the peak pressure.

Shots 1 and 2. Figure 5 shows piezoelectric gage peak pressures obtained on all shots. Comparing those pressures obtained from similar positions on these two shots, it is seen that pressures recorded on the second shot are about one-half of those recorded on the first shot. The pressures recorded at a standoff of 150 feet on shot 2 are lower near the non-detonator end of the charge than off the mid-point of the charge, while those recorded at a standoff of 100 ft on shot 1 are higher near the detonator end of the charge.

Shot 3. No valid comparison between this shot and shots 1 and 2 can be made using piezoelectric gage results. The positions where peak pressures were obtained on the third shot were closer to the charge than were those of shots 1 and 2.

Shot 4. Two peak pressure values (PE-2 and PE-3) obtained on shot 4 are much lower than any peak pressures obtained at the same gage positions on the earlier shots. The third peak pressure (PE-1) measured on the fourth shot is about the same as the peak pressure measured in the same position on shot 3.

4. BALL CRUSHER GAGE RESULTS

Tables 3 through 6 present the ball crusher data in tabular form. The tables list gage position and equivalent step pressure; at some gage positions peak pressure is listed also.

It is necessary to know the shape of the shock wave from pressure-time measurements in order to calculate shock wave peak pressure from ball crusher deformations. For the calculation of the peak pressures here, an average decay rate was calculated from the pressure-time records and the peak pressures were calculated using it. One time constant was calculated from the data of shots 1 and 2 combined and another from the data of shot 4. The time constant found for shots 1 and 2 was used for shot 3 also. Examination of the data showed the fastest decay rate observed would raise these peak pressures by about 10% while the slowest decay rate observed would lower the peak pressures by about 10%. Therefore, it is estimated that the peak pressures are accurate to about $\pm$ 10%.

Equivalent step pressures, - the average pressure over about the first 200 microseconds of the shock wave,- were calculated for all ball crusher gage positions (reference [e]). Only equivalent step pressures were calculated from the gages off the ends of the line charge since no pressure-time measurements were made there.

The deformations of the ball crusher gages on each mine or mine crate were averaged and a single equivalent step pressure calculated for each position. The scatter observed in each group of gages was usually less than 10 percent.

The ball crusher peak pressures include the precursor pressures as do the piezoelectric peak pressures. Correction of the ball crusher results for the precursor was not done as examination of the data showed this correction would be only a few percent.

Shots 1 and 2. Shots 1 and 2 were fired at the same nominal water depth and over the same type of bottom and the data were combined. The equivalent step pressures measured at the same location on the two shots show fairly close agreement at some positions and at other positions differ from each other by a factor of two. In general the shot 2 equivalent step pressures tend to be lower than those of shot 1; this tendency was not expected, since the shot 2 bottom appeared, at least from the size of the crater, to be harder than that of shot 1. However, the effect of the bottom on crater formation may not necessarily correlate with pressure in the water.

In some positions where there were two mines the equivalent step pressures calculated from the two groups of gages differed considerably. In a few positions the difference was as much as 50 per cent. It is believed that most of this difference was caused by shielding of the gages on one mine by the other mine at the same position.

Shot 3. The equivalent step pressures measured on this shot are roughly 40 to 60 per cent lower than those observed on shots 1 and 2. One reason for the observed decrease of equivalent step pressures at the farther positions is the rapid arrival of the surface cutoff caused by the shallow water depth*.

Shot 4. The equivalent step pressures are generally lower than those measured on shots 1 and 2. At standoffs greater than 50 feet the equivalent step pressures of shot 4 are much lower than those of shots 1 and 2 at the same standoff.

5. DISCUSSION

5.1 Limitations of Data: The results reported herein are of limited use in studying the pressure field around a line charge for several reasons.

*Off the detonation end of the charge, the equivalent step pressures on shots 1, 2, and 3 appear to be about the same. However, the data are too scanty for this to be significant.

(a) Variations in the acoustic properties of the bottom. Shock wave propagation near the bottom is strongly influenced by the acoustic properties of the bottom, and these may vary widely. The variations in bottom properties appear to occur over small enough regions to cause variations not only in pressure-time records taken from shot to shot but also in pressure-time records taken from different positions on the same shot. This is believed to be the major cause of pressure variations.

(b) Shielding effects. There appeared to be a shielding effect of the pressure by the mines; i.e., where two mines were close together, low pressures were obtained from one of the sets of gages.

(c) Gage burial. On shot 4, an unknown number of gages were buried in the mud. There was an extreme amount of scatter among various sets of gages on this shot. It is probable that the low values were from gages buried in the mud.

5.2 Shape of the Pressure Field: Figure 6 shows the equivalent step pressures measured around the line charge on shot 2. The pressure field around the line charge as shown by the equivalent step pressures was nearly rectangular. Pressures decreased very rapidly off the ends of the charge. Along most of the length of the charge, lines of constant pressure can be drawn nearly parallel to the charge.

5.3 Comparison of Peak Pressures: Figures 7 and 8 show ball crusher gage average peak pressures and piezoelectric gage peak pressures plotted against distance from the side of the line charge. The ball crusher peak pressures are from gages off the side of the charge. The data of shots 1 and 2 were averaged. Very low peak pressures were discarded for shot 4. A number of the ball crusher gages were buried in the mud on this shot. It was assumed that the low values came from gages in the mud and hence were not representative of pressures in the water. There is no way of determining which gages were buried in the mud and which were not.

The ball crusher peak pressures measured over the hard bottom in 50 ft of water are considerably higher than the corresponding peak pressures measured over a hard bottom in 12 feet of water. The difference is less as the standoff distance from the charge decreases. The ball crusher gage peak pressures measured over the mud bottom are nearly the same as those measured over the hard bottom in 15 feet of water. The average peak pressures measured over the hard bottom fell on a smooth curve while those measured over the mud bottom showed considerable scatter.

There are too few piezoelectric peak pressure points to draw very many conclusions about the agreement with the ball crusher results. However, the piezoelectric gage peak pressures tend to be higher than the corresponding ball crusher peak pressures on the hard bottom shots. The piezoelectric gage peak pressures obtained over mud are in better agreement with the corresponding ball crusher peak pressures.

6. CONCLUSIONS

The results given here are not adequate to define the pressure field around a line charge on the sea floor. Differences in the bottom material, large local variations in the bottom, and water depths are all factors whose effects cannot be computed at present.

This study does give reliable pressure values for the particular conditions studied. Many more measurements would be necessary to increase the accuracy of the results and to delineate completely the pressure field for these conditions.

Further experimental and theoretical studies are needed before pressures under other conditions can be reliably predicted.

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TABLE 2

PIEZOELECTRIC GAGE RESULTS

Gage Mounting	Record	Position X, Y	Precursor Arrival	Shock Wave Arrival	Shock Wave Cutoff	Shock Wave Peak Pressure	Precursor Pressure	Time Constant
			(msec)	(msec)	(msec)	(psi)	(psi)	(msec)
	Shot 1							
Crate	PE-1	- 250,350	43.93	57.31	60.92	1095	126	0.47
Mine	PE-2	-150,350	32.12	39.63	45.13	1265	165	--
Crate	PE-3	-150,500	39.81	47.79	53.48	1475	163	0.44
Crate	PE-4	-150,650	46.49	54.39	59.85	1805	154	0.34
	Shot 2							
Mine	PE-1	100,50	13.84	19.09	None	2715	180	0.38
Mine	PE-2	100,350	27.19	32.40	40.58	1900	250	--
Mine	PE-3	100,650	41.62	46.48	52.81	1680	268	0.60
Mine	PE-4	150,650	49.36	56.72	63.08	865	185	--
	Shot 3							
Crate	PE-1	25,50				5045		
Crate	PE-2	25,350				4360		
	Shot 4							
Crate	PE-1	25,50	None	12.6	18.2	4860	None	0.69
Crate	PE-2	25,350	None	27.1	39.1	2990	None	0.88
Crate	PE-3	100,350	None	41.0	44.1	910	None	--

TABLE 3

BALL CRUSHER EQUIVALENT STEP PRESSURES
AND PEAK PRESSURES
Shot 1

Position (X, Y)	Equivalent Step (psi)	Peak Pressure (psi)	Gage Mounting
150,-150	50	-	Crate
0,-150	75	-	Crate
100,-100	125	-	Crate
0,-100	135	-	Crate
50,-50	680	-	Crate
0,-50	350	-	Crate
-50,-50	470	-	Crate
0,-25	1080	-	Crate
-25,50	5150	6080	Crate
-50,50	3620	4270	Crate
-100,50	2270	2680	Crate
-150,50	840	1050	Crate
-200,50	380	480	Crate
-300,50	190	240	Crate
100,200	2160	2550	Crate
-100,200	1640	2050	Crate
-200,200	660	820	Crate
250,350	290	360	Mine
250,350	390	490	Mine
200,350	510	640	Mine
200,350	390	490	Mine
150,350	980	1160	Mine
150,350	1130	1330	Mine
100,350	1180	1480	Mine
100,350	1140	1430	Mine
-50,350	2320	2740	Mine
-50,350	2580	3040	Mine
-75,350	2530	2990	Crate
-100,350	2020	2380	Mine
-100,350	2220	2620	Mine

TABLE 3

BALL CRUSHER EQUIVALENT STEP PRESSURES
AND PEAK PRESSURES
Shot 1

Position (X, Y)	Equivalent Step (psi)	Peak Pressure (psi)	Gage Mounting
-150,350	870	1090	Mine
-150,350	590	740	Mine
-200,350	540	680	Crate
-250,350	410	510	Crate
-300,350	430	540	Crate
200,500	560	700	Crate
175,500	620	760	Crate
150,500	830	1040	Crate
125,500	1120	1400	Crate
100,500	1470	1840	Crate
75,500	2950	3480	Crate
50,500	3700	4370	Crate
25,500	5600	6610	Crate
-100,500	2130	2510	Crate
-150,500	1090	1290	Crate
-200,500	560	700	Crate
-25,650	4810	5680	Crate
-50,650	3760	4440	Crate
-100,650	1200	1500	Crate
-150,650	980	1230	Crate
-200,650	390	490	Crate
-300,650	220	270	Crate
0,725	1370	-	Crate
50,750	1070	-	Crate
0,750	660	-	Crate
-50,750	710	-	Crate
0,800	120	-	Crate
-100,800	100	-	Crate
0,850	85	-	Crate
-150,850	65	-	Crate

TABLE 4

BALL CRUSHER EQUIVALENT STEP PRESSURES
AND PEAK PRESSURES
Shot 2

Position (X, Y) (feet)	Equivalent Step Pressure (psi)	Peak Pressure (psi)	Gage Mounting
0,-150	75	-	Crate
0,-100	75	-	Crate
-71,-71	75	-	Crate
53,-53	170	-	Mine
0,50	160	-	Crate
-53,-53	125	-	Mine
35,-35	270	-	Mine
0,-25	680	-	Crate
-35,-35	510	-	Mine
100,50	1170	1460	Mine
75,50	2450	2890	Mine
-25,50	4600	5430	Crate
-50,50	3670	4330	Mine
-100,50	1170	1460	Mine
-150,50	630	790	Crate
-200,50	390	490	Crate
-300,50	170	210	Crate
200,200	550	690	Crate
175,200	690	860	Crate
150,200	520	650	Mine
125,200	1060	1250	Mine
125,200	580	730	Mine
100,200	1140	1350	Mine
100,200	940	1180	Mine
50,200	3750	4430	Crate
25,200	4800	5660	Crate
-50,200	2130	2510	Mine
-50,200	3700	4370	Mine
-100,200	970	1210	Mine
-200,200	560	700	Crate

TABLE 4

BALL CRUSHER EQUIVALENT STEP PRESSURES
AND PEAK PRESSURES

Shot 2

Position (X, Y) (feet)	Equivalent Step Pressure (psi)	Peak Pressure (psi)	Gage Mounting
150,250	1290	1610	Cable*
100,250	1980	2340	Cable*
-100,250	1340	1680	Cable*
-200,250	Mine lost		Cable*
125,300	1260	1580	Cable*
-125,300	1690	1990	Cable*
100,325	1210	1430	Mine
100,325	920	1150	Mine
300,350	310	390	Crate
200,350	980	1230	Mine
150,350	530	660	Mine
150,350	480	600	Mine
125,350	1030	1220	Mine
125,350	860	1080	Mine
100,350	1280	1510	Mine
100,350	1150	1440	Mine
75,350	1870	2210	Mine
75,350	1940	2290	Mine
-50,350	2340	2760	Mine
-50,350	3150	3720	Mine
-75,350	1910	2250	Mine
-75,350	1720	2030	Mine
-100,350	1910	2250	Mine
-100,350	1430	1790	Mine

* A moored mine was at this position. The gages were approximately at mid-depth.

TABLE 4

BALL CRUSHER EQUIVALENT STEP PRESSURES
AND PEAK PRESSURES
Shot 2

Position (X, Y) (feet)	Equivalent Step Pressure (psi)	Peak Pressure (psi)	Gage Mounting
-150,350	1110	1390	Mine
-200,350	550	690	Crate
-300,350	205	260	Crate
100,375	1430	1690	Mine
100,400	2120	2500	Mine
100,400	1010	1260	Mine
150,450	560	700	Mine
50,450	2680	3160	Mine
-50,450	2780	3280	Mine
-150,450	680	850	Mine
100,500	1270	1590	Mine
25,500	3740	4410	Mine
-25,500	4730	5580	Mine
-100,500	1650	1950	Mine
75,550	1380	1730	Mine
-75,550	2050	2420	Mine
150,650	350	440	Mine
125,650	910	1140	Mine
100,650	1210	1430	Mine
-25,650	5060	5970	Crate
-50,650	2890	3410	Mine
-75,650	2270	2680	Mine
-100,650	1230	1540	Mine
-150,650	750	940	Crate
-200,650	520	650	Crate
-300,650	300	380	Crate
0,725	1880	-	Crate
35,735	590	-	Mine
-35,735	910	-	Mine

TABLE 4

BALL CRUSHER EQUIVALENT STEP PRESSURES
AND PEAK PRESSURES
Shot 2

Position (X, Y) (feet)	Equivalent Step Pressure (psi)	Peak Pressure (psi)	Gage Mounting
53,753	155	-	Mine
0,750	500	-	Crate
-53,753	205	-	Mine
0,800	115	-	Crate
0,850	50	-	Crate

TABLE 5

BALL CRUSHER EQUIVALENT STEP PRESSURES
AND PEAK PRESSURES
Shot 3

Position (X, Y)	Equivalent Step Pressure (psi)	Peak Pressure (psi)	Gage Mounting
0,-150	185	-	Crate
0,-100	205	-	Crate
0,-50	280	-	Crate
-53,-53	175	-	Crate
18,-18	3040	-	Mine
0,25	1440	-	Crate
-18,-18	640	-	Mine
37-1/2,50	1800	2120	Mine
25,50	1490	1760	Crate
25,50	3110	3670	Mine
-12-1/2,50	7620	8990	Mine
-25,50	2930	3460	Mine
-50,50	2320	2740	Crate
-75,50	1170	1380	Crate
-100,50	560	660	Crate
-150,50	300	380	Crate
150,200	370	460	Mine
150,200	240	300	Mine
125,200	310	380	Mine
125,200	250	310	Mine
100,200	810	960	Mine
100,200	730	860	Mine
75,200	820	970	Mine
75,200	970	1140	Mine
50,200	1430	1690	Mine
50,200	1280	1510	Mine
37-1/2,200	1870	2210	Mine
37-1/2,200	2350	2770	Mine
25,200	3110	3670	Mine
25,200	3790	4470	Mine
12-1/2,200	5530	6530	Mine
12-1/2,200	7990	9430	Mine
-12-1/2,200	6560	7740	Mine
-12-1/2,200	8350	9850	Mine

TABLE 5

BALL CRUSHER EQUIVALENT STEP PRESSURES
AND PEAK PRESSURES

Shot 3

Position (X, Y)	Equivalent Step Pressure (psi)	Peak Pressure (psi)	Gage Mounting
-25,200	3890	4590	Mine
-100,200	790	930	Crate
200,350	320	400	Crate
100,350	540	640	Crate
75,350	930	1100	Mine
75,350	750	890	Mine
50,350	1030	1220	Mine
50,350	1540	1820	Mine
37-1/2,350	1500	1770	Mine
37-1/2.350	1260	1490	Mine
25,350	2430	2870	Crate
25,350	2750	3250	Mine
25,350	2490	2940	Mine
12-1/2,350	3960	4670	Mine
12-1/2,350	4000	4720	Mine
-12-1/2,350	7070	8340	Mine
-12-1/2,350	5370	6340	Mine
-25,350	3300	3890	Mine
-25,350	4470	5270	Mine
-37-1/2,350	2890	3410	Mine
-37-1/2,350	2010	2370	Mine
-100,350	750	890	Crate
-150,350	540	630	Crate
75,450	1100	1300	Mine
62-1/2,450	1360	1600	Mine
50,450	1430	1690	Mine
25,450	3080	3630	Mine
125,650	890	1100	Mine
100,650	590	700	Mine
75,650	1410	1660	Mine
25,650	5220	6160	Crate
-12-1/2,650	7000	8260	Mine

TABLE 5

BALL CRUSHER EQUIVALENT STEP PRESSURES
AND PEAK PRESSURES

Shot 3

Position (X, Y)	Equivalent Step Pressure (psi)	Peak Pressure (psi)	Gage Mounting
-25,650	3130	3690	Mine
-37-1/2,650	2770	3270	Mine
-50,650	1700	2010	Crate
-75,650	1060	1250	Crate
-100,650	1170	1380	Crate
-150,650	710	890	Crate
18,718	700	-	Crate
0,725	590	-	Crate
-18,718	660	-	Crate
0,750	140	-	Crate
0,800	75	-	Crate
0,850	140	-	Crate

TABLE 6

BALL CRUSHER EQUIVALENT STEP PRESSURES
AND PEAK PRESSURES

Shot 3

Position (X, Y)	Equivalent Step Pressure (psi)	Peak Pressure (psi)	Gage Mounting
0,-100	105	-	Crate
0,-50	340	-	Crate
0,-25	Not recovered		Crate
75,50	1120	1400	Crate
50,50	990	1230	Mine
37-1/2,50	1760	2070	Mine
25,50	4030	4740	Crate
-25,50	5200	6110	Mine
-37-1/2,50	1810	2260	Mine
-50,50	1740	2170	Crate
-75,50	1310	1640	Crate
-100,50	860	1070	Crate
-125,50	660	825	Crate
-150,50	340	425	Crate
-25,200	4770	5620	Mine
-37-1/2,200	2200	2750	Mine
-50,200	2270	2590	Mine
-75,200	1550	1940	Crate
-100,200	960	1200	Crate
100,350	300	375	Mine
87-1/2,350	340	425	Mine
75,350	600	750	Mine
75,350	430	540	Mine
62-1/2,350	460	575	Mine
62-1/2,350	500	625	Mine
50,350	810	950	Mine
50,350	960	1130	Mine
37-1/2,350	1310	1640	Mine
37-1/2,350	790	990	Mine
25,350	2420	2850	Crate
0,350	2490	2930	Cable*

* Surface buoy was at this position. The gages were approximately 5 feet below the water surface.

TABLE 6

BALL CRUSHER EQUIVALENT STEP PRESSURES
AND PEAK PRESSURES
Shot 4

Position (X, Y)	Equivalent Step Pressure (psi)	Peak Pressure (psi)	Gage Mounting
-25,350	6370	7500	Mine
-25,350	4400	5180	Mine
-37-1/2,350	3370	3960	Mine
-37-1/2,350	3300	3880	Mine
-50,350	1410	1760	Mine
-50,350	2300	2880	Mine
-75,350	1060	1320	Crate
-100,350	240	300	Crate
-125,350	690	860	Crate
-150,350	370	460	Crate
75,450	920	1150	Mine
62-1/2,450	960	1250	Mine
50,450	1420	1780	Mine
25,450	2560	3010	Mine
-37-1/2,450	2300	2880	Cable*
-50,450	1250	1560	Cable*
100,650	560	700	Mine
75,650	900	1120	Mine
50,650	1770	2210	Mine
25,650	4830	5690	Crate
-25,650	2120	2500	Mine
-37-1/2,650	1900	2370	Mine
-50,650	1530	1800	Mine
-75,650	690	860	Crate
-100,650	500	625	Crate
-125,650	240	300	Crate
-150,650	240	300	Crate
0,725	220	-	Crate
0,750	70	-	Crate
0,800	0	-	Crate

* A moored mine was at this position. The gages were approximately at mid-depth.

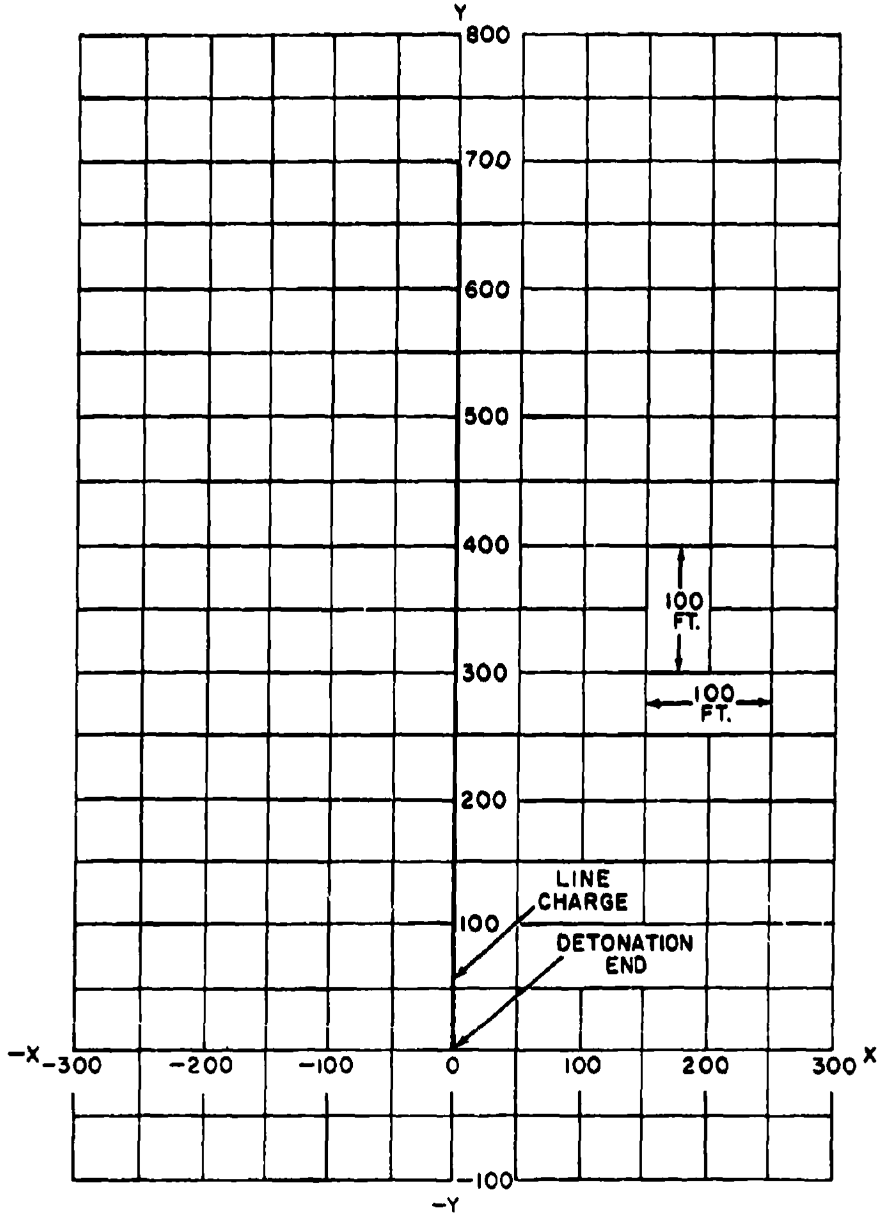


FIG. 1 COORDINATE SYSTEM FOR GAGE LOCATION

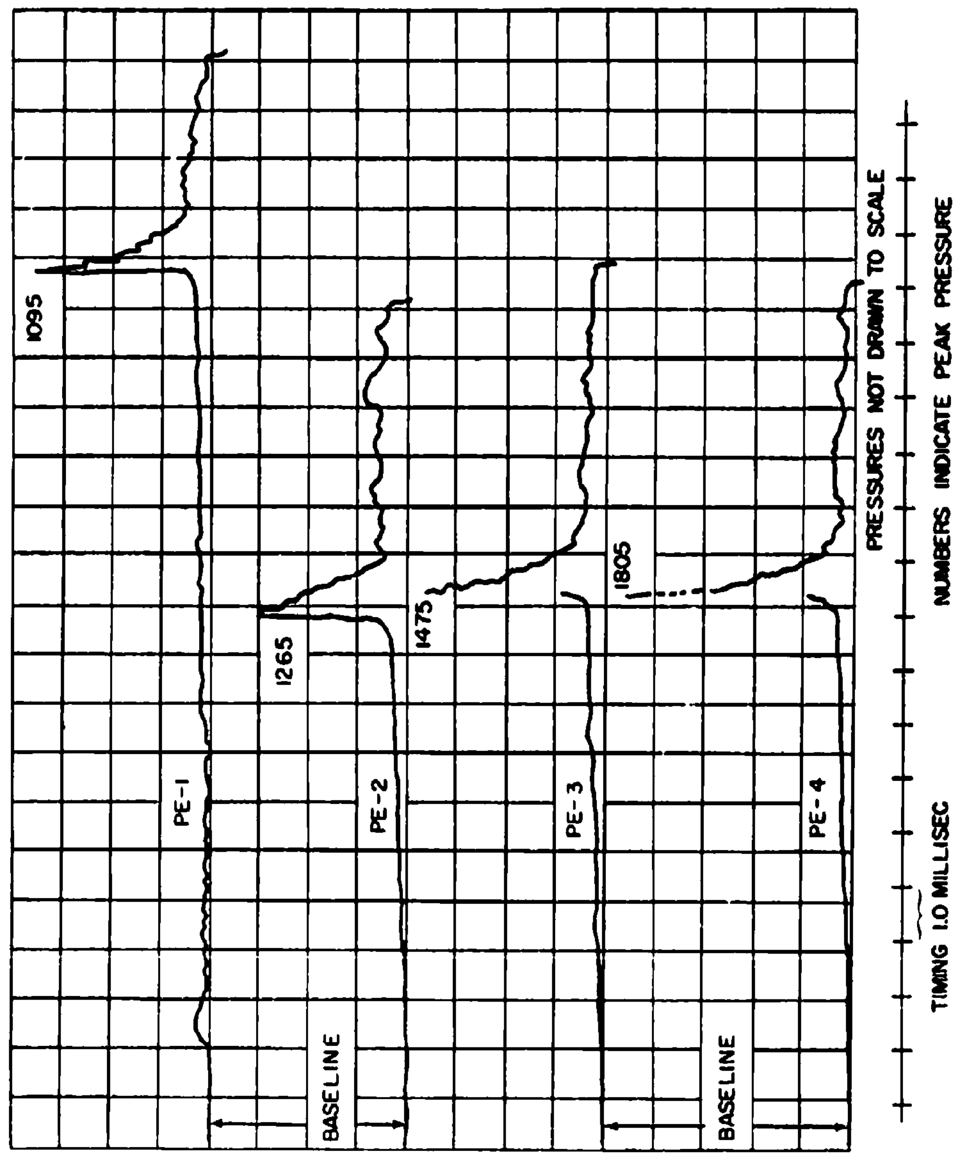


FIG. 2 PIEZOELECTRIC GAGE RECORDS SHOT 1

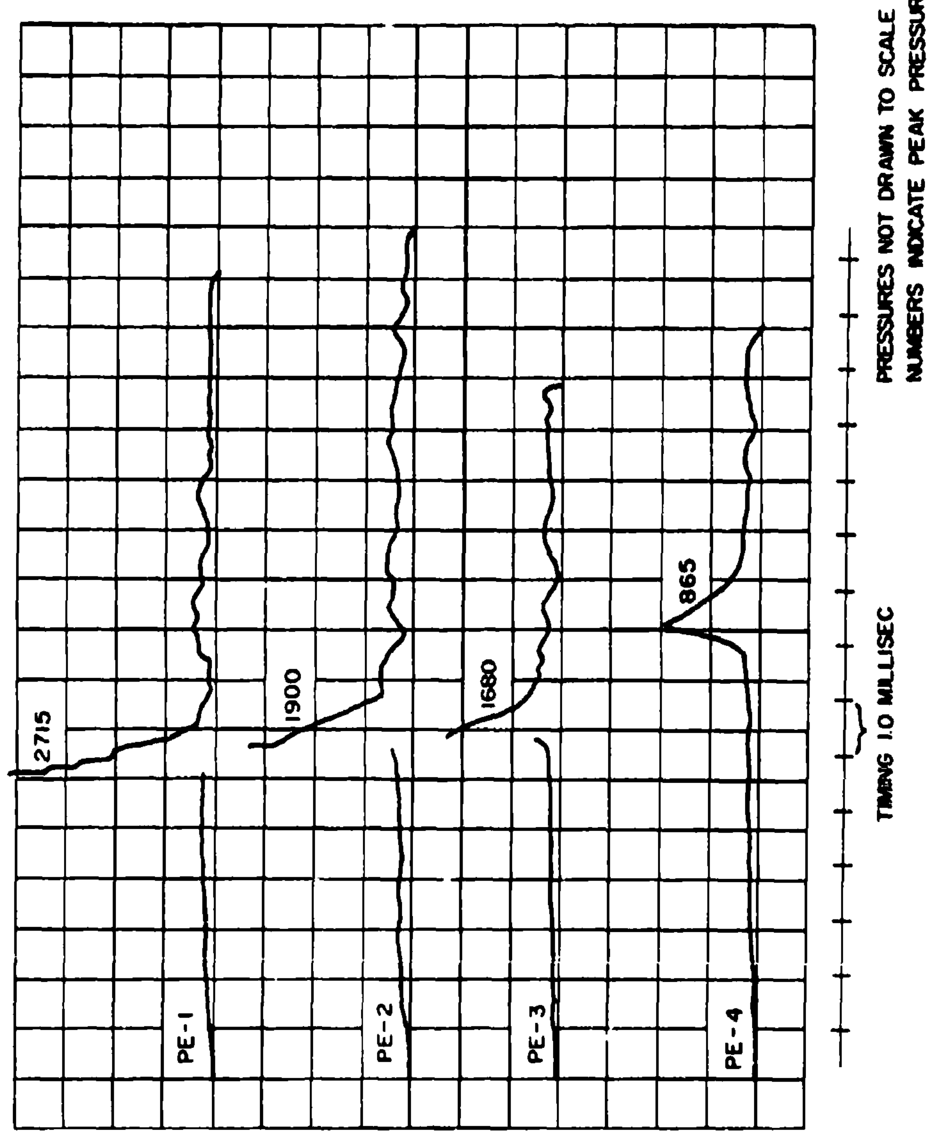
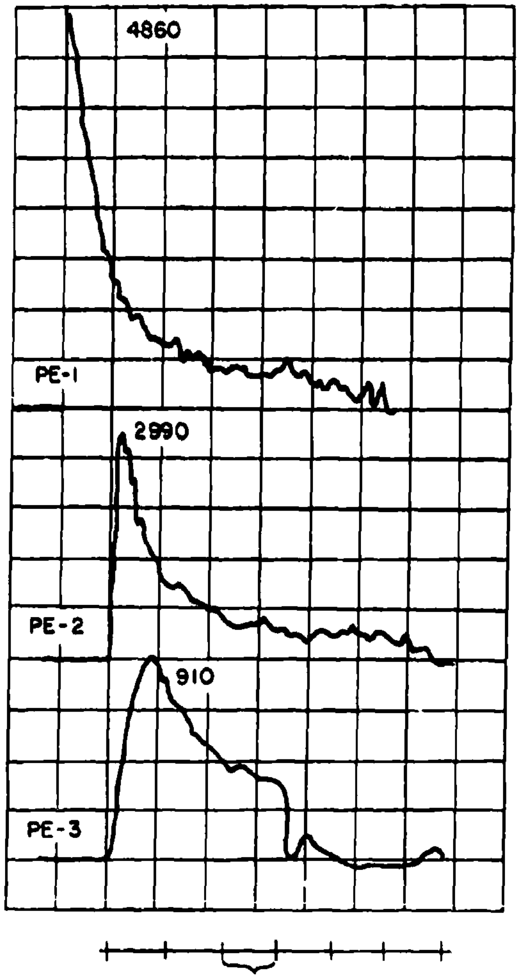


FIG.3 PIEZOELECTRIC GAGE RECORDS SHOT 2



TIMING 1.0 MILLISEC

PRESSURES NOT DRAWN TO SCALE
NUMBERS INDICATE PEAK PRESSURE

FIG. 4 PIEZOELECTRIC GAGE RECORDS SHOT 4

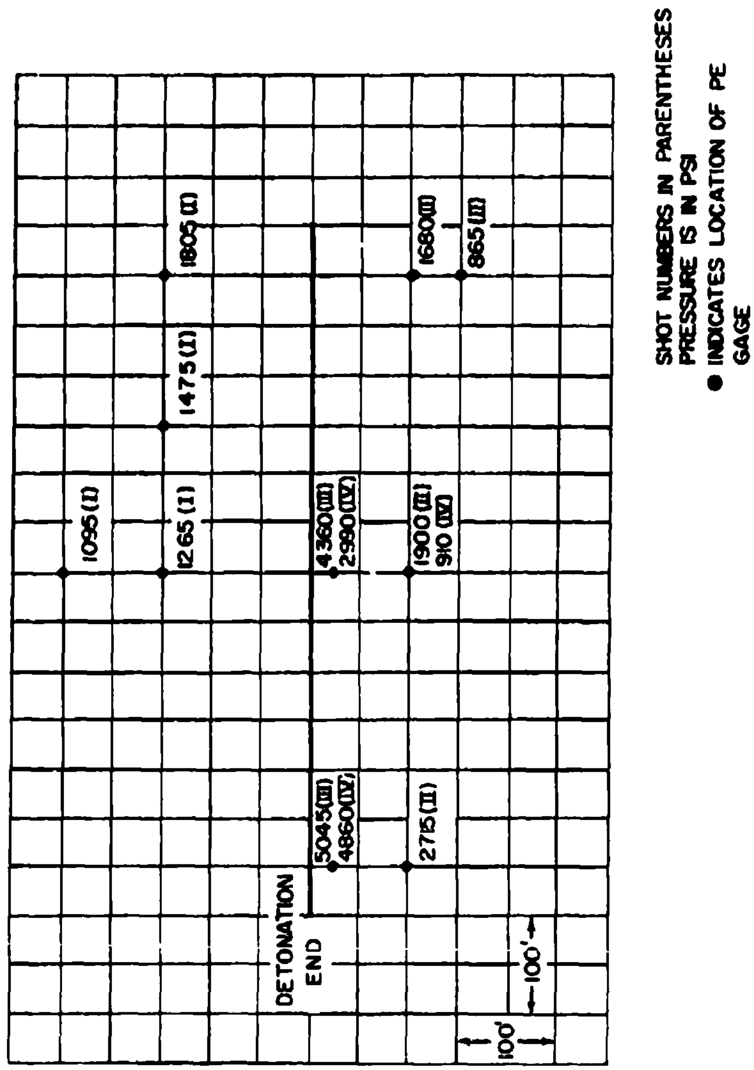
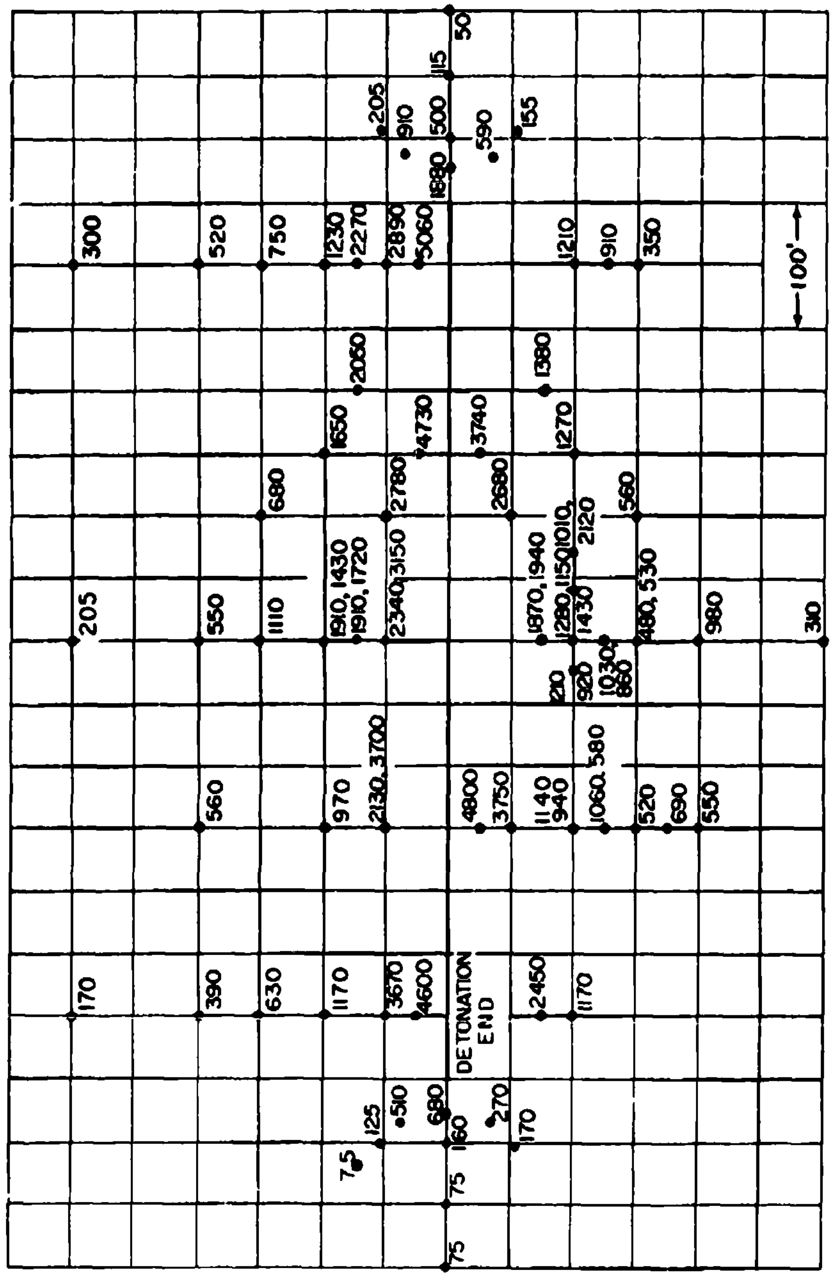


FIG. 5 PIEZOELECTRIC GAGE PEAK PRESSURES FOR SHOTS 1, 2, 3, AND 4



PRESSURES ARE IN PSI

FIG. 6 BALL CRUSHER EQUIVALENT STEP PRESSURES SHOT 2

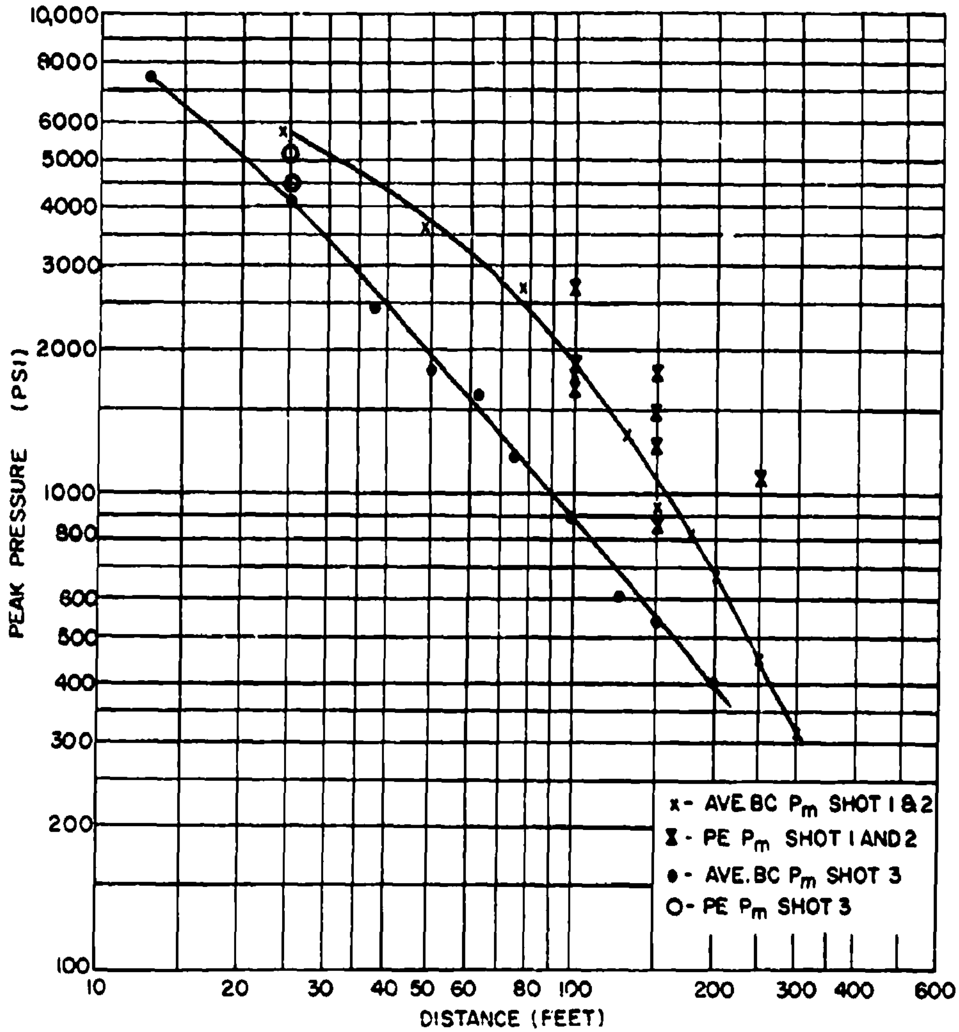


FIG. 7 BALL CRUSHER AND PIEZOELECTRIC PEAK PRESSURES OF HARD BOTTOM SHOTS PLOTTED AGAINST DISTANCE

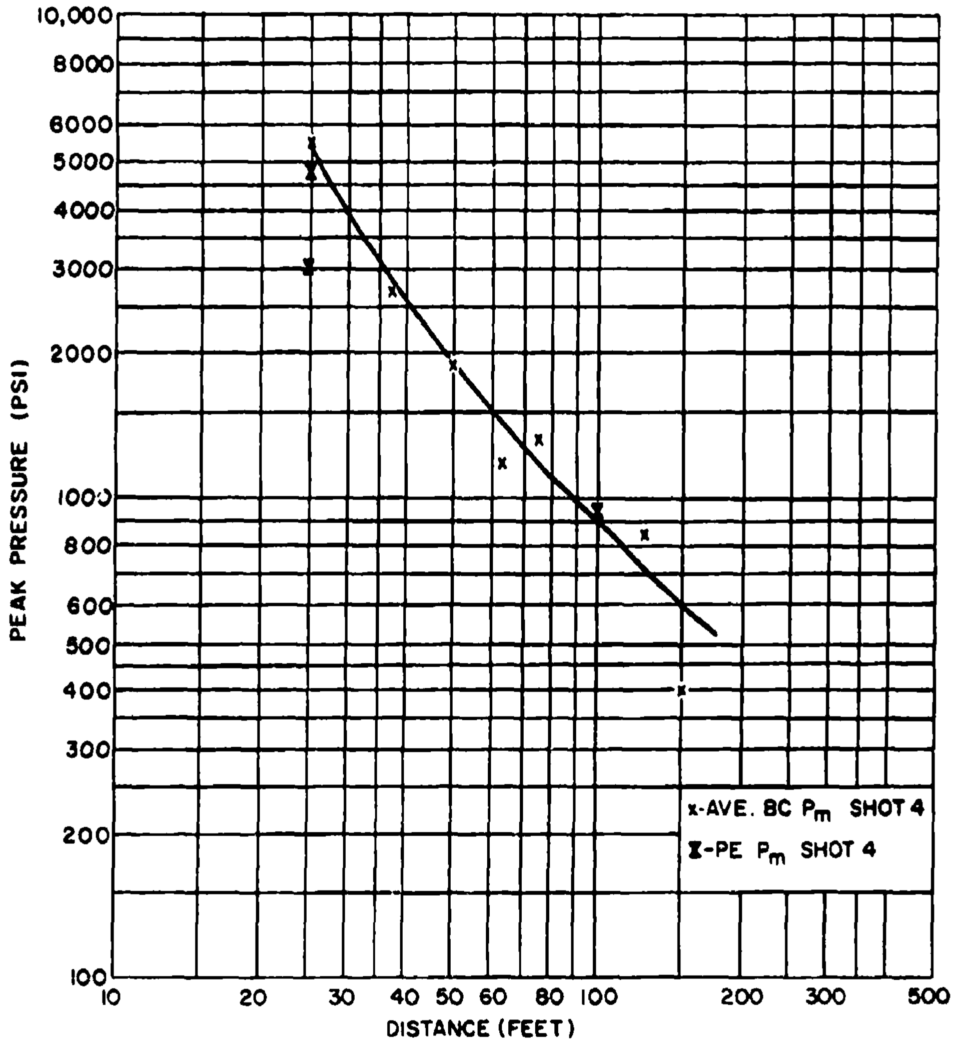


FIG.8 BALL CRUSHER AND PIEZOELECTRIC PEAK PRESSURES OF MUD BOTTOM SHOT PLOTTED AGAINST DISTANCE

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			BIBLIOGRAPHIC (SUPPL., VOL., ETC.)		

SUBJECT ANALYSIS OF REPORT

DESCRIPTORS	CODES	DESCRIPTORS	CODES	DESCRIPTORS	CODES
Shock wave	SHWV	Shock	SHOC	Depth	DEPT
Sand	SAND	Bottom	BOTT	Instrumentation	INSM
Mud	MUDS	Explosives	EXPL	Mine	MINE
Charge	CHAR	Rectangular	RECN	Gage	GAGE
Line	LINE	Pressure field	PREU	Rigging	RIGG
301D	Ø3Ø1	Shape	SHAP	Piezoelectric	PIEZ
Demolitions	DEMO	Scatter	SCAT	Ball	BALL
NOTS	NOTS	Variations	VART	Crusher	CRUS
Coral	CRLS	Minefield	MINF	Peak	PKNG
Underwater	UNDE	Clearance	CLER		
Pressure	PRES	Water	WATR		
Measurements	MEAU	Explosions	EXPS		

PRNC-NOL-5070/28 (5-62)

Naval Ordnance Laboratory, White Oak, Md.
(NOL technical report 63-46)
SHOCK WAVE PRESSURES OVER CORAL SAND AND MUD FROM THE NOTS 301D LINE CHARGE, (U), by M. A. Thiel. 1 March 1963. 21p. illus., tables. WepTask RUME-4E-000/212-1/F008-10-04 PA 002.
CONFIDENTIAL

Underwater pressure measurements obtained on four bottom shots of the NOTS 301D demolition line charge are presented. The pressure field on the bottom around the line charge appeared to be nearly rectangular in shape. Highest pressures were measured from charges over a coral sand bottom in 55 ft. of water. There was considerable scatter among the results due probably to variations in the properties of the bottom along the length of each charge.

Abstract card is unclassified.

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2. Explosions, Underwater - Measurements
3. Charges, Line
I. Title
II. Thiel, Mitchel A.
III. Project

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